THE VARIATIONS OF GLACIERS. XII[1]

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The following is a brief summary of the report of the retiring president of the International Committee on Glaciers, which was presented to the International Congress of Geologists in Mexico in 1906.[2] The committee collects material regarding the variations of glaciers in all parts of the world; this material is collected in different ways in different countries. In Switzerland the Federal Foresters report on the changes in about 90 glaciers, and special work is being done in the study of the Rhone glacier under the auspices of the Helvetic Society of Natural Sciences. The German-Austrian Alpine Club encourages the observations of glaciers in the eastern Alps, the Italian Alpine Club and the Italian Geographical Society help in Italy, and there is a special committee in France which has lately received some help from the government in the observations of glacial variations. The Imperial Russian Geographical Society has done much in collecting and publishing the material regarding the little-known glaciers in the Russian Empire. The Norwegian Tourist Club in Norway, and the Swedish Tourist Club in Sweden have provided for the systematic study of glaciers in those countries, and lately the Swedish Geological Survey and the Reischtag have furnished pecuniary help. The glaciers of Greenland have been studied by exploratory expeditions sent out by the Danish government. Recent information regarding the glaciers of Iceland comes from the explorations of Dr. Thoroddsen; a topographic map now being made shows the positions of many glaciers. In Canada, also, the topographic maps are the most important contributions to glacial work being done by the government, but special studies of Canadian glaciers have been made independently by individuals. The same is true of the glaciers of New Zealand. In India the Geological Survey has undertaken to

[1] The earlier reports appeared in the *Journal of Geology*, Vols. III–XIII.

[2] The complete report will appear in the *Comptes rendus* of the Congress.

keep the record of the movements of some glaciers, but observations there in the past have been very desultory. No systematic work has been done by the government in the United States, although the maps made by the Geological Survey and the Coast and Geodetic Survey in glacial regions are of value in fixing the present positions of the glaciers. Reports regarding the Antarctic and Arctic regions must necessarily be irregular and must be obtained from exploratory expeditions to those regions.

Eleven annual reports have been published by the commission, the first ten in the "Archives des sciences physiques et naturelles," in Geneva. The eleventh report was published in the new *Zeitschrift für Gletscherkunde*, edited by Professor Eduard Brückner, of Vienna, and future reports will appear there. A glance at these reports will show that glaciers in all parts of the world are now retreating. The tendency to advance, which showed itself in the western Alps about 1885 and which slowly passed on to the eastern Alps has now practically disappeared. It did not extend to other glaciated regions.

Since the organization of the committee many theoretical and observational studies of glaciers have been made. It has been shown that when a glacier advances there is first an increase of thickness and of velocity in the higher parts of the glacier and that a wave of greater thickness and greater velocity travels down the glacier and causes an advance of the end; this wave originates in an increased accumulation in the reservoir, and in general the longer the glacier the longer time will be needed for the wave to reach the end. It has also been shown that the greatest thickness in the reservoir will occur some time after the maximum snowfall; so that the advance of the end may be many years after the period of maximum snowfall. If the glacier itself advances sooner than this theory would lead us to expect it must be due to diminished melting at the end, rather than to increased accumulation in the reservoir. The application of the idea of hydrodynamic lines of flow to the motion of glaciers has greatly increased our understanding of glacial phenomena, and it is to the further development and application of this idea that we must look for the increase of our knowledge of glaciers in the near future. The long-continued controversy as to the origin of the blue bands has been at

least partially solved. It has been quite clearly shown that the orderly systems of blue bands in the body of the dissipator are the modified strata; but it has not yet been shown that the bands which exist close to the bed and at the very end of the glacier belong to the above systems.[1]

The following is a summary of the Eleventh Annual Report of the International Committee on Glaciers:[2]

REPORT ON GLACIERS FOR 1905

Swiss Alps.—Of the ninety glaciers under observations in Switzerland, forty-nine were measured in 1905. The changes in five are uncertain; three glaciers are stationary and the other forty-one are in retreat. No glacier measured in 1905 showed any certain advance.[3]

Eastern Alps.—Observations were made in the summer of 1905 on sixty-one glaciers; forty-nine were in retreat, five were stationary, and seven had advanced somewhat, so that the general tendency to retreat still dominates. Of the seven advancing glaciers, five are in the mountains of the Oetzthal, where are situated also three of the stationary glaciers. The other two advancing glaciers are in the Goldberg group of the Hohen Tauern. The Grosselendkees, which is stationary, lies in the Ankogel group, the most easterly part of the Alps bearing glaciers. The Gliederferner in the Zillerthal Alps, which was advancing last year, is now in retreat.

[1] The following changes have been made in the committee. Professor Francesco Porro, formerly representing Italy on the commission, was elected to represent Argentina; Professor Olinto Marinelli succeeded him as representative of Italy; Mr. Charles Rabot, represents France, as the successor to Professor W. Kilian, who has retired; and Dr. E. von Drygalski was elected to report on the Antarctic regions; Professor Brückner was made ordinary member of the commission to represent Austria, succeeding Dr. A. Penck, who has removed to Berlin. Other corresponding members have been added as follows: Professor Dr. Hans Angerer, Mr. Charles Jacob, Mr. A. B. Harper, Major Hon. E. G. Bruce, Mr. W. S. Vaux, Jr., Mr. G. K. Gilbert, General Carlo Porro. Professor Penck and Professor Kilian were elected corresponding members on their withdrawal from the list of ordinary members. The committe lost by death two of its important members, Professor Eduard Richter of Graz, and Professor Israel Russell of Michigan. The following officers were elected to serve until the next meeting of the International Congress of Geologists: Honorary President, Prince Roland Bonaparte, of Paris; Active President, Professor Dr. Eduard Brückner, of Vienna; Secretary, M. Ernest Muret, of Lausanne.

[2] *Zeitschrift für Gletscherkunde*, Vol. I, pp. 161–81.

[3] *Report* of Professor Forel and M. Muret.

In opposition to this general tendency to retreat we notice that certain glaciers of the Oetzthal, which have been retreating pretty rapidly, are now retreating more slowly and some of them are even in a stationary condition.[1]

Italian Alps.—The Italian glaciers do not seem to show any marked variations, but the general tendency is to retreat.[2]

French Alps.—The glaciers in the Grandes Rousses of Dauphiné are in general retreat. A map of these glaciers on a scale of $\frac{1}{10000}$ is now being made. Measures of snowfall in the Savoy have shown a smaller amount in the winter of 1904–5, than in that of 1903–4. Special observations on the Mont Blanc chain have shown that the greatest snowfall occurs at an altitude in the neighborhood of 2,550 meters. The glaciers of Mont Blanc and the Maurienne show a slight retreat though there are indications of increased activity which later may bring on an advance. In the Vanoise and the upper valley of the Arc the glaciers continue to retreat, and some large snow fields have disappeared; others have been broken up by projecting ridges of rock.

Pyrenees.—The glaciers in these mountains are stationary or retreating. There have been very great changes since the middle of the last century; for instance, between 1855 and 1904, the glacier de l'Est has retreated 1,140 meters and the glacier de la Brèche, 1,230 meters. In the last two years there seems to be an increase of snowfall on these glaciers. The disappearance of some small glaciers in the French Alps and in the Pyrenees has been injurious to agriculture on account of the decreased quantity of water available for irrigation. This has led the Minister of Agriculture to offer pecuniary support to glacial observations.[3]

Sweden and Norway.—One glacier was observed in Sweden in 1905, the Mika, and it has retreated three to four meters. In Norway the changes have been mixed, some glaciers have retreated and some have advanced. The three glaciers observed in the Jostedal have advanced from 5 to 19 meters.[4]

[1] *Report* of Dr. H. Angerer.

[2] *Report* of Dr. F. Porro.

[3] *Report* of M. Charles Rabot.

[4] *Reports* of Dr. F. W. Svenonius and M. P. A. Oyen.

Russia.—In the mountain chain of Peter the Great, Boukhara, two glaciers show an advance since 1899, one of them as much as 64 meters. One in the Tian-Chan shows a retreat since 1892.

Caucasus.—Many glaciers have been visited and named; the Bartui has steadily been retreating; the retreat amounted to 30 meters in 1900–1, 12 meters in 1902–3, 13.5 meters in 1903–4. The glaciers of the Caucasus seem to be in general retreat.[1]

British Columbia and Alberta.—The Illecillewaet glacier continues to retreat, but much more slowly; it lost but 2 feet 6 inches between 1905 and 1906, though there has been a general shrinking in the volume of the ice. The tongue of the Asulkan glacier is slowly melting away under the moraine.[2]

South America.—A short description of the glaciers of Poto, just north of Lake Titicaca, Peru, has been given by Otto F. Pfordte.[3] The San Francisco glacier has high terminal moraines, but the present end has not varied much since the Spanish occupation, as shown by the ruins of houses at the foot of the cliff, where the glacier now ends. Old observations and traditions of the natives indicate that the snow-line is gradually receding in this part of the Andes, which accounts for the gradual lowering of the lakes. Mr. Bandelier,[4] referring to this same general neighborhood, states that the glaciers of the Bolivian Andes have been in slow retrocession for a number of years.

Central Africa.—The Mubuhu glacier on the eastern slopes of Ruwenzori is apparently in retreat. An old moraine overgrown with vegetation may be recognized some 500 meters in advance of the existing tongue of the glacier, and from the appearance of the rocks nearby it would seem that a slow retreat is now in progress (1905). Morainic lakes have been observed on the western slope below the limits of the present glaciers by Dr. Stuhlmann.[5]

[1] *Report* of Colonel J. de Schokalsky.

[2] *Report* of Messrs. G. and W. S. Vaux.

[3] "The Glaciers of Poto, Peru," *Proceedings of Eighth International Geographical Congress*, Washington, 1904, pp. 497–500.

[4] *Bulletin of the American Geographical Society*, 1905, Vol. XXXVII, p. 454; also *Scottish Geographical Magazine*, 1905, Vol. XXI, p. 586.

[5] *Report* of Mr. D. W. Freshfield.

REPORTS ON THE GLACIERS OF THE UNITED STATES FOR 1906[1]

The snow fall in the Rocky Mountains in the summer of 1905 was very heavy and perhaps for that reason the Hallet Glacier shows a slight advance (*Mills*). But there has been a slight retreat at the north end of Arapahoe Glacier, which is not far from the Hallet (*Henderson*). The glaciers in the Montana Rockies are either stationary or slightly retreating (*Chaney*). A small glacier reported in Bighorn Mountains of Wyoming has apparently disappeared (*Salisbury*).

On the north side of Mt. Hood, Washington, Eliot Glacier is diminishing very markedly. The ice is growing much thinner at the end and a more rapid retreat will probably appear before long. Some of the snowfields are greatly altered and the ascent of the mountain has been rendered much more difficult than heretofore (*Mrs. Langille*). On the south side of Mt. Hood, the White Glacier has diminished in thickness but does not seem to have receded materially (*Montgomery*). Glacier Peak, in Washington, was climbed last summer by Mr. C. E. Rusk. He found that the glaciers showed signs of retreat but less than in other places in Washington; these glaciers carry comparatively little débris. Mount Baker was visited last summer by the Mazama Club, of Portland, Oregon; their magazine contained many excellent pictures of the glaciers and a sketch map of the mountain, showing a number of distinct glaciers, but no information is given as to the recent changes. When this mountain was visited in 1903 by Messrs. Rusk and Campbell there was a small, well-marked crater at the summit, about 50 feet in diameter, from which considerable volumes of black smoke were rolling away. In 1906 this vent was completely filled with snow and no evidence of its existence appeared except a slight depression in the surface of the snow (*Rusk*).

Last summer Messrs. F. E. and C. W. Wright visited Glacier Bay and repeated the survey which was made in that region in 1892. They found very remarkable changes in all the glaciers. The only definite information we have had of any of these glaciers since 1899,

[1] A synopsis of this report will appear in the *Twelfth Annual Report* of the International Committee. The report of the glaciers of the United States for 1905 was given in this *Journal*, Vol. XIV, pp. 406–10.

until the Messrs. Wright's visit, was due to a trip to Muir Glacier by Messrs. Andrews and Case, in May, 1903, and they reported a very considerable recession in that glacier.[1] The report of the Messrs. Wright will not be published before next winter but they have very kindly prepared an abstract of the glacial changes which they observed as follows;[2]

On comparing our map with your map of 1892, the following changes are most apparent: Beginning with Muir Glacier and its tributaries the ice front has receded a maximum distance of about 33,000 feet; Dirt Glacier is no longer tidal; White and Adams Glaciers are supplying very little ice to the general ice field; Morse Glacier terminus is about one mile from tide water; the crest of the stagnant ice mass between Girdled Glacier and Muir Inlet has melted down about 200 feet since the time of your measurements; Girdled Glacier and Berg Lake, however, have not changed materially in aspect. The length of the total ice front of Muir Glacier is now over 40,000 feet instead of 9,000 feet in 1892. The present ice front passes at its northern extremity at about the position of your 1,000 feet contour on the ice of 1892. This remarkable decrease in elevation is undoubtedly due not only to melting down but also to breaking down of the exposed ice masses. The ascent of the ice mass at this point is decidedly steep and the ice fairly cascades into the water. The present height of the ice fronts of all the tide water glaciers is about the same as noted by you in 1892 (150′–250′), and is a noteworthy fact in connection with these glaciers. Muir Inlet is at present choked by the ice pack which promises to remain congested so long as its source of supply is so active. A considerable portion of the present front of Muir Glacier is in very shallow water and in a few years should decrease in size very materially unless new avenues and inlets for tidal currents are exposed by the receding ice. Dying Glacier is still creeping back and wasting away.

Carroll Glacier has not changed much in aspect during the last 14 years; its terminal cliff has receded about 2,000 feet and at present, apparently, is continuing to do so. It is discharging icebergs very slowly and Queen Inlet is nearly free of ice.

Rendu Glacier has also changed but little and its front is about 2,000 feet back of its position in 1892. This Inlet also is not impeded by any amount of ice. The small glacier cascading from the west near its terminus appears to have changed still less.

In Reid Inlet the changes have been very great and things are still moving at a

[1] C. L. Andrews, "Muir Glacier," *National Geographical Magazine*, 1903, Vol. XIV, pp. 441–45, and this *Journal*, 1904, Vol. XII, p. 258. The positions of the glaciers in 1899 are described by G. K. Gilbert in the *Harriman Alaska Expedition*, Vol. III.

[2] A map of this region accompanies an article on "Glacier Bay and Its Glaciers," in the *Sixteenth Annual Report of the United States Geological Survey*, 1894–95.

rapid rate there. The inlet was congested with the ice pack last summer and on the south side near the large island the ice jam was completely frozen over and moved as one mass back and forth with the tides.

Grand Pacific Glacier has receded and left the large granite island surrounded by water. It has receded nearly 20,000 feet; but judging from the amount of ice it is now discharging and the shape of its valley it will not recede so rapidly in the next few years, other conditions remaining the same.

Johns Hopkins Glacier has receded about 11,000 feet and is still sending off icebergs at a rapid rate. The unnamed glacier directly east has become detached from it and is much like Reid Glacier in character and appearance.

Reid Glacier has receded perhaps 5,000 feet and still preserves its original aspect as indicated on your map.

The small dying glacier between Reid and Hugh Miller Glaciers has practically disappeared. At least no ice was visible in the rock and moraine débris.

Hugh Miller Glacier no longer reaches tide water in Reid Inlet and at low tide is nearly a mile back from it. The tide flats are long and with only a slight grade. In Hugh Miller Inlet this glacier was exposed to tide water only in the southwestern bay, where its front is intercepted in its central part by a large promontory of light colored granite. Eight thousand feet is approximately its amount of recession since 1892. Charpentier Glacier also receded about 9,000 feet and promises to continue its recession rapidly, especially along its southern front as its valley is opening out and allowing a greater exposure of ice front to the action of tide water.

The small stagnant glacier east of Charpentier is simply melting away and will probably disappear in ten or twenty years.

Favorite Glacier is still receding. Wood Glacier is no longer tidal and only a small part of Geikie Glacier ice front is exposed to salt water. Geikie Glacier has receded about 5,000 feet during the past 14 years.

On the whole, recession has been the rule for the glaciers of Glacier Bay. Those glaciers have receded most whose ice fronts have, on recession, increased appreciably in length. In the past 14 years the combined ice front of all the glaciers exposed to tide water has increased from 17,000 feet to over 40,000 feet and the amount of recession has in that time alone equalled that of the previous 20 years.

To the west of Glacier Bay, Brady Glacier in Taylor Bay has receded considerably. In Lituya Bay, the glacier at the northwestern end of the bay has advanced about one-half mile since 1894; the central and southeastern glaciers have apparently remained unchanged although the latter may have advanced slightly.

The two glaciers at the ends of the bay were reported in 1894 to be about three kilometers in advance of their positions of 1786. It is curious that the glaciers of Lituya Bay should be advancing, while those of Glacier Bay, about fifty kilometers to the east, are retreating so markedly.

It will be remembered that when Professor Tarr visited the region about Yakutat Bay in 1905 he found that the glaciers showed a general tendency to retreat, though the changes were not very great for tide-water glaciers. When he visited the region again in 1906, remarkable changes had taken place. The Marvine Glacier, to the west of Yakutat Bay, supplies the ice for the eastern part of the Malaspina Glacier; though all previous explorers had found it comparatively smooth and easily traversed, it had become greatly broken and crevassed. The glaciers next to the east, the Hayden and the Lucia, showed no such changes, whereas the Atrevida, next to the Lucia, exhibited changes similar to those of the Marvine. The Seward Glacier, farther west, which is the largest glacier supplying the Malaspina, seemed to be more crevassed than it was when crossed by the Duke of the Abruzzi in 1900, but was not broken and torn like the Atrevida and the Marvine. The part of the Malaspina Glacier which derives its ice from the Marvine, was full of crevasses for a distance of twelve to fifteen miles. The southern border of the Malaspina Glacier, which was formerly stagnant ice completely covered with moraine and heavy vegetation, has been so broken up that great blocks of ice are falling from the end, the moraine is sliding off, and the trees have been overturned. The Turner Glacier, which enters the western side of Disenchantment Bay showed no decided changes, whereas, the Haenke, a small glacier lying immediately north of the Turner, was advancing into the water; it had joined the end of the Turner Glacier and had thus lengthened the ice front by about a mile. The great Hubbard Glacier, which comes in from the north, showed no change, whereas the Orange Glacier immediately to the southeast, which in 1905 was smooth and easily traveled, was so broken in 1906 that even the lower part could not be traversed, and the region of stagnant ice covered by moraine had been transformed into clear ice, crevassed and pinnacled. That these remarkable changes had taken place between the summers of 1905 and 1906 is clearly shown by the observations and photographs of Professor Tarr; and that the advance, at least at the end of the Malaspina Glacier, was still in progress, was shown by the fact that the overturned trees had put forth their leaves in the early summer before being uprooted. The fact that certain glaciers, presenting, so far as

could be observed, no special characteristics, had experienced such changes, whereas adjoining ones had not, makes it evident that these changes were not due merely to general climatic conditions, but to some special cause. Professor Tarr suggests that this cause was the severe earthquakes which occurred in this region in September, 1899, and which brought about marked changes of level, in some places amounting to 40 feet.[1] Professor Tarr thinks that these earthquakes shook down enormous quantities of snow and ice from the surrounding mountains and thus added so large a supply to the reservoirs or to the upper parts of the dissipators of some of the glaciers as to cause a sudden and great increase in the velocity, resulting in a strong thrust, which produced abundant crevasses. Some glaciers, on account of the forms of the surrounding mountains, may not have received such great additions to their masses; and others, on account of greater length, may require several years before the change is shown in their lower portions. Professor Tarr's explanation seems entirely satisfactory and is supported by the observation of Mr. A. H. Brooks, who in September, 1899, was on the eastern side of the St. Elias chain and reports that he heard unusually large avalanches falling from the mountains. Examples are known of glaciers which have advanced when neighboring glaciers were retreating, due to the protection of their surfaces by avalanches of snow or by land slides; but the present case seems to be far more remarkable than any heretofore reported and it is greatly to be hoped that observations will be continued and the future changes recorded.[2] At present we only have sketch maps of these regions, but at some future time, when better maps are made we may be able to show more clearly the causes of the different behavior of the various glaciers.

[1] Ralph S. Tarr and Lawrence Martin, "Recent Changes of Level in the Yakutat Bay Region, Alaska," *Bulletin of the Geological Society of America*, 1906, Vol. XVII, pp. 29–64.

[2] Professor W. H. Sherzer has described some moraines in the Canadian Rockies, made up entirely of large blocks of rock. He thinks that this material may have been shaken down upon the glaciers by earthquakes. See "Glacial Studies in the Canadian Rockies and Selkirks," *Smithsonian Miscellaneous Collections*, 1905, Vol. XLVII, Part. 4, pp. 494–96.